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California Electric Rule 21 Supplemental Review Guideline

Developed by:
California Energy Commission
Rule 21 Working Group

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1. Introduction

This Guideline is intended support the standardized implementation of interconnection requirements defined in the California Electric Rule 21¹. In particular, this Guide addresses Generating Facility (GF) Interconnection Applications that have failed one or more of the Rule 21 Initial Review Process (IRP) screens and are undergoing Supplemental Review.

For the Electric Corporation (EC) engineer, this guideline provides basis for performing the Supplemental Review in a manner consistent with other engineers and other ECs, and for focusing their efforts on what are generally agreed to be the primary issues of concern. For the Applicant or DR provider, this document can act as a primer on the topics addressed by the IRP, as a guide to possible solutions when IRP failure is anticipated, and as a basis for understanding the EC's decision as a result of a Supplemental Review.

The IRP was designed as a first order EC system impact study and is designed to approve systems that should have no impact on the distribution system to which they are to be connected. Supplemental Review is intended to provide a slightly more detailed review of the conditions that caused the system to fail the IRP and determine if

1. no additional requirements are necessary to allow interconnection,
2. some additional requirements or changes (to the GF, the EC distribution system, or both) are necessary to allow interconnection, or
3. a more detailed system impact study is necessary (the cost and schedule for the study are also provided).

The pass/fail criteria in the IRP screens represent, for the most part, collective engineering judgment and are not absolute. For example, Screen 4 asks if the aggregate generation capacity on the line section to which the GF is to be connected exceeds 15 percent of the line section peak load. This screen was not meant to imply that generation above the 15 percent mark, or, for that matter, that 16 or 22 percent, would be unacceptable. It flags interconnection applications that may begin to impact distribution system operation, safety, or reliability.

While the defined steps in the IRP may be performed by an individual with only a cursory understanding of the distribution system, a qualified EC engineer will perform the Supplemental Review. Supplemental Review allows the engineer the opportunity to evaluate the proposed GF at its intended location.

Beyond the screening process in each Major issue, this Guide does not provide specific steps or methods of evaluating the proposed GF, thus leaving latitude in its interpretation. However, by defining the issues that are to be considered for each IRP screen failure and general ways of dealing with those issues, it is expected that the guide will promote a consistent implementation of Rule 21 requirements in those ECs that adopt them.

¹ California Electric Rule 21 - Generating Facility Interconnections

2. Definitions

The definitions here are supplementary to and in some cases expand upon those provided in Rule 21.

Accessible, visible, lockable, disconnect: This device is used by EC maintenance personnel to ensure that the GF will not energize the line during maintenance activities. The device meeting this requirement may or may not also serve as an NEC-required isolation means. Each of the qualifying terms is discussed below.

Accessible – means the device is accessible to EC maintenance personnel at all times. Accessible has to do with convenience—it can't be located in a crawl space or attic. You must be able to access it without a ladder or other special equipment. In some cases, it may be in a locked room, if arrangements can be made with the EC to ensure they have a key. There is no specific requirement that the device be located at the PCC or revenue meter, however, if the disconnect serving this purpose is located away from the PCC/revenue meter, the location of the disconnect must be clearly marked on the submitted single line diagram and permanent signage must be installed at the PCC/Meter location providing a clear description of the location of the disconnect.

Visible - In this case, visible means visible break—when the disconnect is in the open position, there is a visible separation between the contacts, and that separation may be observed without disassembling the device. Typically, this switch contains visible blades inside an enclosure, an external lever, and a positive indication that the switch is in the off position. A molded case breaker, for example, does not meet this requirement. This requirement does not imply that the open disconnect be visible at all times (e.g. through a window in the enclosure). A fused disconnect meets this requirement even though the disconnect must be opened to see the visible break. A reversible fuse block, where the block installed in the reverse position provides an open connection, may serve this purpose as well.

Lockable - The disconnect must have provisions for a common 3/8" padlock, used as part of normal EC maintenance lockout procedure.

Line Section: (From Rule 21) *That portion of EC's Distribution System connected to a Customer bounded by automatic sectionalizing devices or the end of the distribution line.*

Note that a given GF may have several line sections that need to be considered, as shown in the example below. Normally, no more than two automatic devices and the end(s) of the distribution line should be considered at a time.

Example: Consider Generating Facilities G1, G2, and G3 connected to a distribution feeder with a substation circuit breaker, a line recloser, and a set of sectionalizing fuses as shown in Figure 1.

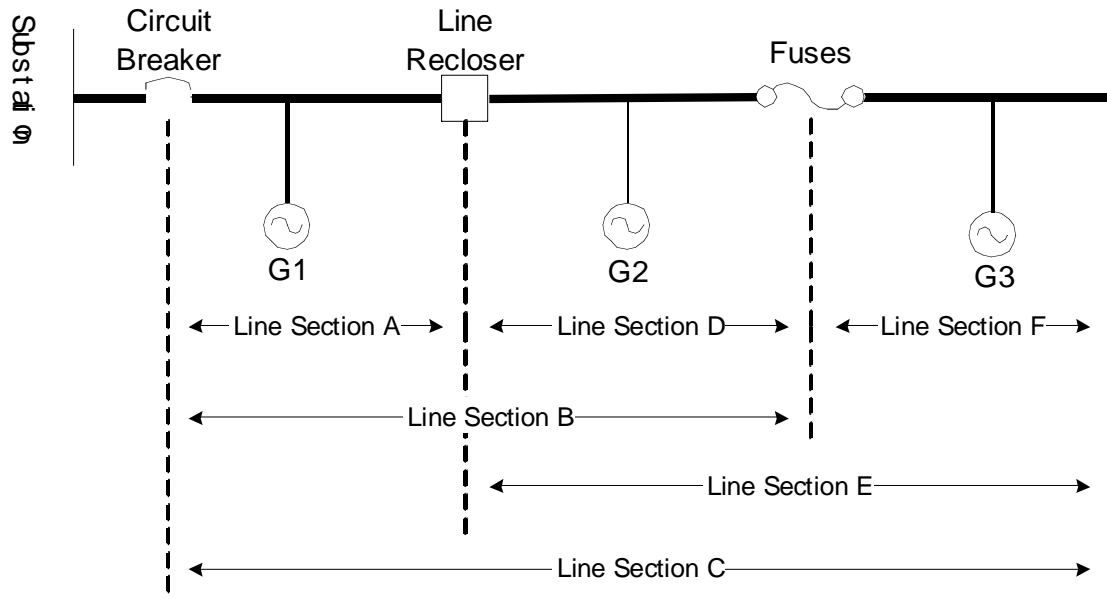


Figure 1 Line Section Example

Isolation Possibilities

1. If just the circuit breaker opens, G1, G2, and G3 are all isolated on Line Section C, which is bounded by the circuit breaker and the end of the distribution line.
2. If the circuit breaker and line recloser open, G1 is isolated on Line Section A, which is bounded by the circuit breaker and the line recloser. Meanwhile, G2 and G3 are isolated on Line Section E, which is bounded by the line recloser and the end of the distribution line.
3. If the circuit breaker and fuses open, G1 and G2 are isolated on Line Section B, which is bounded by the circuit breaker and the fuses. Meanwhile G3 is isolated on Line Section F, which is bounded by the fuses and the end of the distribution line.

Line Section Review

- Generating Facility G1: reviewed as a subset of Line Sections A, B, and C respectively.
- Generating Facility G2: reviewed as a subset of Line Sections B, C, D and E, respectively.
- Generating Facility G3: reviewed as a subset of Line Sections C, E, and F respectively.

Sample numbers

Generator G1 capacity: 1000kW

Generator G2 capacity: 100kW
Generator G3 capacity: 200kW
Line Section A load: 5000kW
Line Section B load: 9000kW
Line Section C load: 10,000kW
Line Section D load: 5000kW
Line Section E load: 1000kW

Calculating the aggregate generating capacity percentages for each Line Section:

Line Section A: Aggregate % = $G1/A = 1000/5000 = \underline{20\%}$
Line Section B: Aggregate % = $(G1 + G2)/B = 1100/9000 = \underline{12\%}$
Line Section C: Aggregate % = $(G1 + G2 + G3)/C = 1300/10,000 = \underline{13\%}$
Line Section D: Aggregate % = $(G2 + G3)/D = 300/5000 = \underline{6\%}$
Line Section E: Aggregate % = $G3/E = 200/1000 = \underline{20\%}$

Therefore, considering each generator individually as the Applicant in an Initial Review,

- Generator G1 would fail the 15% screen for Line Section A only. Supplemental Review would then deal with Line Section A only
- Generator G2 would pass the 15% screen
- Generator G3 would fail the 15% screen for Line Section E only, triggering a Supplemental Review dealing with Line Section E only

Penetration - % of load on circuit
 % of circuit breaker
 % of line section

Short Circuit Contribution Ratio (SCCR) is the ratio of the GF's short circuit contribution to Electrical Corporation's short circuit contribution for a three-phase fault at the high voltage side of the distribution transformer connecting the GF to Electrical Corporation's system.

$$SCCR = \frac{SCC_{GF}}{SCC_{EC}}$$

where

SCC_{EC} = short circuit contribution of EC to a 3_ fault at the high side of the distribution transformer connected to GF exclusive of other GFs.

SCC_{GF} = short circuit contribution of GF to a 3_ fault at the high side of the distribution transformer connected to GF (symmetrical, based on sub-transient reactance).

Aggregate SCCR is the sum of the individual SCCR values of the GF's on the circuit (including applicant SCCR). For the three GFs depicted in Figure 2, the individual and aggregate SCCR are given by the following equations:

$$SCCR_1 = \frac{SCC_{GF1}}{SCC_{EC1}}; \quad SCCR_2 = \frac{SCC_{GF2}}{SCC_{EC2}}; \quad SCCR_3 = \frac{SCC_{GF3}}{SCC_{EC3}}$$

$$\text{Aggregate SCCR} = SCCR_1 + SCCR_2 + SCCR_3$$

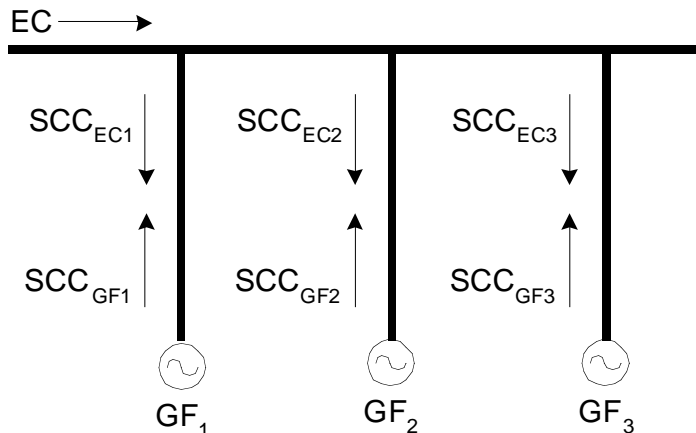


Figure 2 Aggregate SCCR example

The Aggregate SCCR is a screening parameter used to determine if the increase in short circuit current on the Distribution Circuit due to the addition of GF is significant enough to warrant further study. The calculation described here is a simplification that provides an estimate of SCCR without going through a fault study. No attempt should be made to correlate the value of the Aggregate SCCR with the actual short circuit current at any point on the Distribution Circuit. The actual short circuit currents are determined by performing a comprehensive short circuit study, which is beyond the scope of the Supplemental Review process in nearly all cases.

3. References

California Electric Rule 21:

Generating Facility Interconnections (PG&E, SCE)

Interconnection Standards for Non-Utility Owned Generation (SDG&E)

The Existing Language presented under each Screen in Section 6 is representative of the text in the approved Rules for each of the three California Investor-Owned Utilities as of December 2002. Slight variations may exist between the text shown and a specific EC Rule.

4. Using This Guideline

This Guideline is formatted to facilitate the evaluation of GF Interconnection Applications that have failed one or more of the Rule 21 Initial Review Process Screens. The following lists the suggested steps:

- 1) **Complete the IRP Process.** This step is necessary so that all of the necessary information is collected and so that the reviewer is certain which issues must be dealt with in the Supplemental Review.
- 2) **Compile the list of failed IRP Screens.**
- 3) **Compile the list of relevant Questions for each failed screen.** Proceed to the sections (under Section 6) corresponding to the failed screens. A table in each of those sections contains a list of additional Supplemental Review questions that need to be answered.
- 4) **Obtain answers for each of the Questions.**
- 5) **Compile List of Major Issues.** The appropriate section for each screen lists the Major Issues associated with that Screen and the Section numbers of where those issues are discussed. Note that each Major Issue needs to be addressed only once even though it may be raised in more than one screen.
- 6) **Perform Specified Review.** For each Major Issue, go to the appropriate section (either in Section 6 or Section 7) and perform the review specified.

5. Rule 21 Technical Requirements

This section summarizes the technical requirements defined in Rule 21 Section D as of December 2002. The reader is referred to the current EC-specific version of the Rule for details and the latest requirements.

Protective Functions Required.

- Over and under voltage / over and under frequency trip functions with disconnect means
- Automatic means to prevent the GF from energizing a de-energized circuit and to prevent reconnect unless the service voltage and frequency is of specified settings and is stable for at least 60 seconds
- A means to mitigate contribution to Unintended Island
- Generating Facility shall be designed so that the failure of any one device shall not potentially compromise the safety and reliability of the EC Distribution System.

Momentary Paralleling GFs. A transfer switch or system used to transfer the Producer's loads may be allowed by the EC in lieu of the Protective Functions required for Parallel Operation.

Suitable Equipment Required. Interrupting devices (i.e. circuit breakers) located at the PCC must be Certified or "Listed" as suitable for their intended application.

Visible Disconnect Required. GF greater than 1 kVA aggregate shall include a manual, lockable, accessible Visible Disconnect to isolate the GF from the EC.

Maximum Single-Phase GF Nameplate Rating.

- Shared secondary - 20 kVA max
- Imbalance - maximum of 6 kVA of imbalance between the two sides of a center-tapped 240-volt service.
- Dedicated transformer: - transformer nameplate rating

Drawings Required. GF protection and control diagrams must be approved by the EC. Certified or previously approved equipment may satisfy this requirement.

Prevention of interference.

GF shall not superimpose a voltage or current on the Distribution System that interferes with service to EC's customers or communication facilities. If such interference occurs, the Producer must diligently pursue and take corrective action at its own expense after being given notice and reasonable time to do so by Electrical Corporation.

To eliminate undesirable interference caused by operation of the GF, each GF shall include means of meeting the following:

Voltage @ PCC ⁽²⁾	Range		Max Trip Time ⁽¹⁾	
	Volts-120V base	%	Cycles	Seconds
Fast Under	$V_{POC} < 60$	$< 50\%$	10	0.167
Under	$60 \leq V_{POC} < 106$	50% - 88%	120	2.0
Normal	$106 \leq V_{POC} \leq 132$	88% - 110%	Normal Operation	
Over	$132 < V_{POC} < 165$	110% - 138%	120/30 ⁽³⁾	2.0/0.5 ⁽³⁾
Fast Over	$V_{POC} > 165$	$> 138\%$	6	0.1
Frequency ⁽²⁾	Range		Max Trip Time ⁽¹⁾	
	Hz – 60 Hz base	%	Cycles	Seconds
Under	< 59.3	99.2%	10	0.167
Normal	59.3 - 60.5	98.8 - 100.8	Normal Operation	
Over	> 60.5	100.8	10	0.167
Flicker	GF should not cause the voltage at the PCC to exceed the limits defined by the “Maximum Borderline of Irritation Curve” in IEEE STD 519-1992.			
Harmonics ⁽²⁾	GF harmonic distortion shall be in compliance with IEEE STD 519-1992. Exception: shall be evaluated using the same criteria as for the loads at that site.			
Power Factor	Between 0.9 leading and lagging. Operation outside this range may be acceptable for PF correction purposes or if otherwise allowed by EC.			
Direct Current Injection	$\leq 0.5\%$ of GF rated output current			

(1) - “Maximum Trip time” – maximum allowable time between the onset of the abnormal condition and the GF ceasing to energize the Distribution System.

(2) - For GF ≤ 11 kVA; set points may be fixed. For GF > 11 kVA, set points and trip times shall be field adjustable and different voltage set points and trip times may be negotiated with EC.

(3) - Trip times are for GF ≤ 11 kVA/ > 11 kVA

Technology-specific requirements

Three-Phase Synchronous Generators

- Circuit breakers shall be three-phase devices with electronic or electromechanical control
- regulate power factor, not voltage.
- Power system stabilization not required for GF < 10 MW.
- SCCR \leq 0.05: GF synchronizing function may be either manual or automatic.
- SCCR > 0.05: GF synchronizing function shall be automatic; GF shall be equipped with loss of synchronism Protective Functions

Induction Generators

- Do not require a synchronizing function
- Starting or rapid load fluctuations on induction generators can adversely impact the Distribution System's voltage. Corrective step-switched capacitors or other measures installed on the Producer's side of the PCC must be reviewed. Additional equipment may be required as determined in a Supplemental Review or an Interconnection Study.

Inverter-based Systems

- Do not require separate synchronizing equipment
- Non-utility-interactive or “stand-alone” inverters shall not be used for parallel operation.

Supplemental Requirements

Unintended Islanding Mitigation for GF that Fail the Export Screen: GF must mitigate potential contribution to an Unintended Island by:

- incorporating certified Non-Islanding control functions
- verifying that local loads sufficiently exceed the GF Net Nameplate Rating
- incorporating transfer trip or equivalent Protective Function.

Fault Detection. For SCCR > 0.1 or GF that do not meet any one of the Unintended Islanding options above shall be equipped with Protective Functions designed to detect Distribution System faults, both line-to-line and line-to-ground.

- For a GF that cannot detect these faults within two seconds, transfer trip system or equivalent may be required.
- Reclose-blocking may also be required for GF that exceed 15% of the peak load on the Line Section.

6. Supplemental Review

The Rule 21 list of IRP screens provides the organizational basis for the following sections. For each screen, there is a discussion of the technical issues involved, options for resolving those issues, the additional data and analysis or review that may be necessary to determine which of the potential outcomes discussed in Section 1 (interconnect as is, interconnect with changes, perform system impact study) should result.

6.1. Screen 1 - Networked Secondary

Guidance for this section is under consideration for a future revision of this document.

6.2. Screen 2 - Power Export

The following issues need to be evaluated for GF that intentionally export power (i.e. net-metered systems), as well as those GF that may export power incidentally (i.e. due to operational transients). Export means that the aggregate generation at a Producer's facility exceeds the aggregate load, and the net power flows to the EC distribution system.

A primary concern regarding the interconnection of Distributed Resources on the EC distribution system is the injection of power at locations not designed for that purpose. With the exception of a few potential issues like short-circuit current contribution, harmonics, etc., non exporting systems—those that meet one of the four options under Screen 2—are, equivalent to “negative” loads. Systems that intend to export power have increased potential for islanding, and may impact EC voltage regulation or exceed equipment rating. .

6.2.1 Existing Rule 21 Language

2. Will power be exported across the PCC?

*If Yes, DG does not qualify for Simplified Interconnection.
Perform supplemental review.*

If No, DG must incorporate one of the following four options:

Option 1:

To insure power is never exported, a reverse power Protective Function must be implemented at the PCC.

Default setting shall be 0.1% (export) of transformer rating, with a maximum 2.0 second time delay.

Option 2:

To insure at least a minimum import of power, an under-power Protective Function must be implemented at the PCC.

Default setting shall be 5% (import) of DG Gross Nameplate Rating, with maximum 2.0 second time delay.

Option 3:

To limit the incidental export of power, all of the following conditions must be met:

- The aggregate DG capacity of the Generating Facility must be no more than 25% of the nominal ampere rating of the Customer's Service Equipment;*

- *The total aggregate DG capacity must be no more than 50% of the service transformer rating (This capacity requirement does not apply to customers taking primary service without an intervening transformer);*
- *The DG must be certified as Non-Islanding.*

Option 4:

To insure that the relative size (capacity) of the DG compared to facility load results in no export of power without the use of additional devices, the DG capacity must be no greater than 50% of the Customer's verifiable minimum annual load.

Significance:

1. *EC's Distribution System does not need to be studied for load-carrying capability or DG power flow effects on EC voltage regulators since on-site DG reduces EC load.*
2. *Permits use of reverse-power relaying at the PCC as positive anti-islanding protection.*

6.2.2 Questions Relevant to this Screen

Answers for all of the following questions should be obtained to facilitate the evaluation process that follows.

- **Applicant capacity** - What is the GF kW capacity of this Application?
- **Applicant export** - What is the maximum expected export? Note that "0" means that one of the non-export options of Screen 2 has been met
- **Applicant technology** - What is the technology (synchronous, induction, inverter) for this application?
- **Certified Non-Islanding** - Does the proposed equipment include a Certified Non-Islanding function?
- **Additional Features** - Does the proposed GF incorporate any additional features beyond those required in Rule 21 or unique operational characteristics that should be considered?
- **Aggregate percentage** - What is the aggregate generating capacity relative to the peak Line Section load (in %)?
- **Aggregate export** - What is the aggregate peak export on the Line Section relative to the peak Line Section load?
- **Aggregate technologies** - What are the technologies of other GF on the Line Section?
- **Relative capacities** - What are the relative capacities of other GF on the Line Section?
- **Location** - Where is the Applicant GF relative to other GF on the Line Section?
- **Unique features** - Are there unique operating/design features for the affected Line Section?
- **Voltage regulation** - How is the distribution voltage regulated on the affected Line Section?

6.2.3 Issues Relevant to this Screen

The three Major Issues for exporting systems and the Sections in which they are addressed are

Unintentional Islanding– Section 7.1

Voltage Regulation– Section 7.2

EC Equipment Rating– Section 7.3

Proceed to the Major Issue Sections noted above and determine a course of action necessary for each issue.

6.3. Screen 3 - Certified Equipment

It is the intent of this screen to review a non-certified unit for interconnection. This supplemental review addresses the required information and source of that information.

6.3.1 Existing Rule 21 Language

Screen 3: Is the Interconnection Equipment Certified for the Application or does the Interconnection Equipment have Interim Electrical Corporation Approval?

- *If No, the Generating Facility does not qualify for Simplified Interconnection. Perform Supplemental Review.*
- *If Yes, continue to next screen.*

Significance:

If the Generating Facility has been Certified or previously approved by Electrical Corporation, Electrical Corporation does not need to repeat its review and/or test of the Generating Facility's Protective Functions scheme. Site Commissioning Testing may still be required to insure that the system is connected properly and that the protective functions are working properly.

Additional note: EC may, at its discretion, use previous test results/experience with proposed equipment to accept the equipment without further review or testing. EC may, at its discretion, witness test or elect a 3rd party to witness any or all tests described in section J.3.A performed as commissioning tests. EC will define which tests are needed for the given application. Equipment may be field tested and certified by a nationally recognized testing laboratory (NRTL), or as required by the EC, equipment may be field tested by a testing facility acceptable to the EC, and the test reports submitted to the EC for approval. EC may require additional information from Applicant regarding prior test data and design details, which would be reviewed under the Supplemental Review. A determination would be made regarding the need for any further test data. For example, non-certified but previously approved equipment may be subject to additional testing if

1. The proposed protection or control schemes differ from the previously approved equipment.
2. There is a change to the size of the unit.
3. The proposed GF has different number of generating units than the one previously approved.
4. The GF is proposed for a Network interconnection.
5. The proposed GF has failed other Rule 21 screens.

Equipment may be supplemented with EC approved protection schemes to eliminate need for some or all certification tests (not including pre-parallel verification). If the facility is comprised of units that have been previously tested and approved by EC, then additional testing may not be required.

A proposed GF consisting of individually approved or certified components that have not been certified or approved as a unit may require EC review to verify the proper application of the components and additional commissioning testing as specified in Rule 21 Section J.5.c, J.5.d, and J.5.e.

6.3.2 Questions Relevant to this Screen

Answers for all of the following questions should be obtained to facilitate the evaluation process that follows.

- **Applicant export** What is the maximum expected export? Note that “0” means that one of the non-export options of Screen 2 has been met
- **Applicant technology** What is the technology (synchronous, induction, inverter) for this application?
- **Applicant technology experience** Is the interconnection equipment the same or of a similar class as currently installed and approved in EC territory?
- **External mitigation equipment** Does the applicant design incorporate EC approved protective relays, filters, etc..., either as part of the Generator Facility or pre-existing in the customer facility?

6.3.3 Issues Relevant to this Screen

Certification indicates the following criteria have been tested and verified: These same criteria must be verified for non-certified equipment.

Prevention of Interference

System Protection— Section 7.8

1. Basic protective function requirements—Rule 21, Section D.2.
2. Synchronizing requirements. (if needed)
3. Non-islanding requirements. (if needed)
4. Reverse power function requirement. (if needed)
5. Under-power function requirement. (if needed)

Power Quality— Section 7.9

6. Power factor regulation requirements.
7. Harmonic distortion limits.
8. DC injection limits

Proceed to the Major Issue Sections noted above and determine a course of action necessary for each issue.

6.4. Screen 4 - 15% Line Section Peak Load

The 15% line section peak load screen is meant as a catchall for a variety of potential problems that can occur as the level of penetration of generation within the distribution system increases.

6.4.1 Existing Rule 21 Language

Screen 4: Is the aggregate Generating Facility capacity on the Line Section less than 15% of the Line Section Peak Load?

- *If Yes, continue to next screen.*
- *If No, Generating Facility does not qualify for Simplified interconnection. Perform Supplemental Review to determine cumulative impact on Line Section.*

Significance:

Low penetration of Generating Facility installations will have a minimal impact on Distribution System and load operation and power restoration.

The operating requirements for a high penetration of Generating Facilities may be different since the impact on EC's Distribution System operation will no longer be minimal, therefore requiring additional study or controls.

Additional note: If one can assume as a rule of thumb that the typical line section minimum load will be at least 30% of the peak load, at 15% aggregate, the generating capacity would be no more than 50% of the minimum load of the Line Section. In this case, the generation would be adequately swamped out by the load during an islanded condition.

6.4.2 Questions Relevant to this Screen

Answers for all of the following questions should be obtained to facilitate the evaluation process that follows.

- **Applicant capacity** - What is the GF kW capacity of this Application?
- **Applicant export** - What is the maximum expected export? Note that "0" means that one of the non-export options of Screen 2 has been met
- **Applicant technology** - What is the technology (synchronous, induction, inverter) for this application?

- **Certified Non-Islanding** - Does the proposed equipment include a Certified Non-Islanding function?
- **Additional Features** - Does the proposed GF incorporate any additional features beyond those required in Rule 21 or unique operational characteristics that should be considered?
- **Aggregate percentage** - What is the aggregate generating capacity relative to the peak Line Section load (in %)?
- **Aggregate export** - What is the aggregate peak export on the Line Section relative to the peak Line Section load?
- **Aggregate technologies** - What are the technologies of other GF on the Line Section?
- **Relative capacities** - What are the relative capacities of other GF on the Line Section?
- **Location** - Where is the Applicant GF relative to other GF on the Line Section?
- **Unique features** - Are there unique operating/design features for the affected Line Section?
- **Voltage regulation** - How is the distribution voltage regulated on the affected Line Section?

6.4.3 Issues Relevant to this Screen

The three issues of concern for exporting systems and the Sections in which they are addressed are

Unintentional Islanding– Section 7.1

Voltage Regulation– Section 7.2

EC Equipment Rating– Section 7.3

Proceed to the Major Issue Sections noted above and determine a course of action necessary for each issue.

6.4.4 Additional Data Required from Applicant

- Any GF-specific operational characteristics or features.

6.4.5 Additional Analysis Required by EC

- Distribution system load flow- normal (peak and minimum load) and abnormal circuit configurations
- Voltage profile studies
- Equipment loading studies
- Review of voltage regulator control settings
- Review of other connected DG units on Line Section (capacities, types (synchronous, induction, inverter), mode of operation)

- Review of recloser intervals at sectionalizing device (circuit breaker, service restorer)
- Distribution System fault studies

6.4.6 Potential Interconnection Study Items

- Distribution system load flow
- Equipment loading
- Distribution System fault studies
- Protective device coordination review and studies
- Transient analysis
- Stability studies

6.5. Screen 5 - Starting Voltage Drop

Guidance for this section is under consideration for a future revision of this document.

6.6. Screen 6 - GF Capacity >11kVA

Guidance for this section is under consideration for a future revision of this document.

6.7. Screen 7 - Short Circuit Current Contribution

The intent of this section is to provide simple tests for determining either that the proposed GF's short circuit current contribution will have an insignificant impact on the Electrical Corporation's Distribution System or that additional studies are required. This section also provides some guidance for additional study requirements for those GFs that fail the tests.

6.7.1 Existing Rule 21 Language

Screen 7: Is the Short Circuit Current Contribution Within Acceptable Limits?

- *If No, the Generating Facility does not qualify for Simplified Interconnection. Perform Supplemental Review.*
- *If Yes, continue to next screen.*

Short Circuit Current Contribution Screen :

The Short Circuit Current Contribution Screen consists of two criteria; both of which must be met when applicable:

- (1) *At primary side (high side) of the Dedicated Distribution Transformer, the sum of the Short Circuit Contribution Ratios (SCCR) of all Generating Facilities on the Distribution System circuit may not exceed 0.1.*
- (2) *At secondary (low side) of a shared distribution transformer, the short circuit contribution of the proposed Generating Facility must be less than or equal to 2.5% of the interrupting rating of the Producer's Service Equipment.*

Significance:

No significant Generating Facility impact on:

- (1) *Distribution System's short circuit duty*
- (2) *Distribution System fault detection sensitivity*
- (3) *Distribution System relay coordination*
- (4) *Distribution System fuse-saving schemes*

If the Generating Facility passes this screen it can be expected that it will have no significant impact on Electrical Corporation's Distribution System's short circuit duty, fault detection sensitivity, relay coordination or fuse-saving schemes.

Additional Note: Because of their low fault duty capabilities (typically less than twice rated current) inverter-based GFs are unlikely to cause problems related to Short Circuit Contribution (SCC).

6.7.2 Questions Relevant to this Screen

Answers for all of the following questions should be obtained to facilitate the evaluation process that follows.

- **Applicant SCCR** (from IRP) – What is the GF SCCR of this Application?
- **Applicant Short Circuit Current SCC_{GF}** – What is the short circuit current contribution in amperes (or MVA) of the Applicant's GF?
- **Maximum Continuous Short Circuit Current Capability** – What is the Applicant GF sustainable fault current (after 2 seconds) output capability into a 3-phase high-side fault?
- **Dedicated Transformer** – Is the GF served by a dedicated transformer?
- **Aggregate GF Short Circuit Current** – What is the total short circuit current contribution in amperes (or MVA) from all of the GFs if they were connected at the same location?
 $Aggregate\ SCC_{GF} = SCC_{GF1} + SCC_{GF2} + SCC_{GF3}$
- **Aggregate SCCR** (from IRP) – What is the aggregate generator SCCR on the Distribution Circuit?
- **Location on the Distribution Circuit** – Where is the Applicant GF relative to other GFs on the Distribution Circuit?

- **Protective Device Sensitivity** - For EC Protective Devices: Expressed as a multiple of minimum trip, **MMT** (ratio of the end of line fault duty to the relay minimum trip), for overcurrent devices or expressed as a percent of reach, **%Z**, for impedance devices. These values are calculated without the proposed GF.
- **Relay Desensitization** - What is the effective desensitization of the EC relays due to GF short circuit current in-feed?
- **Equipment Rating Margins** – What are the margins in amps (or MVA) between the equipment short circuit ratings on the Distribution Circuit and the maximum calculated short circuit duties (provided by Fault Study)?

6.7.3 Issues Relevant to this Screen

The two issues of concern for generators that contribute short circuit current to distribution system faults are

- EC Equipment Short Circuit Current Rating – Section 7.4
- Protective Device Sensitivity and Coordination – Section 7.5

Proceed to the Major Issue Sections noted above and determine a course of action necessary for each issue.

6.7.4 Additional Data

- GF continuous short circuit current capability. Excitation system characteristics should be considered. What is the Applicant GF sustainable fault current (after 2 seconds) output capability into a 3-phase high-side fault?
- Neighboring customer equipment ratings may be required for shared secondary transformers
- Distribution system fault studies (normal and alternate configurations)
- Distribution system load flow – normal (peak and minimum load) and abnormal circuit configurations
- Review other connected DG units on Line Section (capacities, types (synchronous, induction, inverter), mode of operation)
- Recloser intervals at sectionalizing device (circuit breaker, service restorer)
- Distribution system transient studies (generator out of phase synchronization)
- If secondary short circuit current is high on shared distribution transformer, review interrupting ratings of other connected customers

6.7.5 Potential Interconnection Study Items

If supplemental review fails to define an appropriate solution, the following issues may need to be addressed in a more detailed interconnection study:

- Distribution load flow

- Distribution System fault studies
- Device interrupting rating review
- Protective device coordination studies
- Transient analysis
- Stability studies
- Distribution design alternatives on shared transformer secondary

6.8. Screen 8 – Line Configuration

Guidance for this section is under consideration for a future revision of this document.

7. Major Issues

Each of the sections below discusses a major issue of importance to one or more of the Screens. The details of the issue are discussed, followed by an issue-specific review process. This review process is an expanded version of the Initial Review Process, providing pass fail criteria and resulting in a quantitative and qualitative basis for making a decision on how to proceed with the application.

7.1. Unintentional Islanding

For unintentional islanding to occur a number of specific conditions must exist. Rule 21 (Section D.3.a.1), requires synchronous generators to regulate power factor, not voltage, but it is understood that under certain conditions, synchronous generators may be able to provide the stable voltage control required to sustain an island condition.

1. **GF must be exporting**—the non-export options defined in IRP Screen 2 are intended to provide positive anti-islanding function². GFs that export (e.g., net-energy metered systems) have an increased potential for islanding with loads beyond the PCC.
2. **Aggregate GF must have the capacity and load-following capability to carry the associated load (in kW) of the island.**
3. **GF within the island must be capable of providing the reactive requirements (in kVAR) to sustain the operation of the interconnected GF while serving the reactive requirements of the connected load.** Even though a given synchronous generator in an island is not exporting, it can still provide the excitation requirements to allow for sustained island operation if other technologies (inverter, induction) are interconnected and there is adequate generating capacity to serve the connected load.

² Technically, the significance section only mentions the use of reverse power relaying as positive anti-islanding, but under power relaying and compliance with minimum load criteria meets this definition as well.

4. **The condition that creates the island must not otherwise be detected by the GF.** This requirement implies that the loss of utility does not result in a fault within the island that can be detected by any of the GF within the island. If the loss of utility DOES result in a high impedance fault, that fault must meet all of the other listed conditions.
5. **Additional conditions for Inverter-Based and Induction GF-** In analyzing the operation of inverter-based systems isolated with load (and without other DG technologies (synchronous, induction) interconnected in the island), the following discussion is presented
 - a. **Aggregate GF real power output must be nearly equal to the aggregate real power load.** For GFs that do not load follow when exporting, the range of the required load to generation ratio is proportional to the square of the under and over voltage trip settings range. The Rule 21 voltage trip settings of -12%/+10% of nominal lead to a power balance (load/generation) requirement of roughly 77% - 121%, assuming a constant impedance load.
 - b. **The islanded load circuit quality factor Q must be high enough to stabilize the GF.** For GF not attempting to regulate EC distribution voltage, there is a natural tendency (or a designed anti-islanding function) to shift the output voltage or frequency. For the GF to island, this tendency must be offset by a minimum resonance or circuit quality, Q:

$$Q = R\sqrt{\frac{C}{L}} = \frac{\text{RealPower}}{\text{ReactivePower}}$$

For the non-islanding certification test, a Q of 2.5 is used, which is equivalent to an uncorrected power factor, PF = 0.37, as shown in Figure 3.

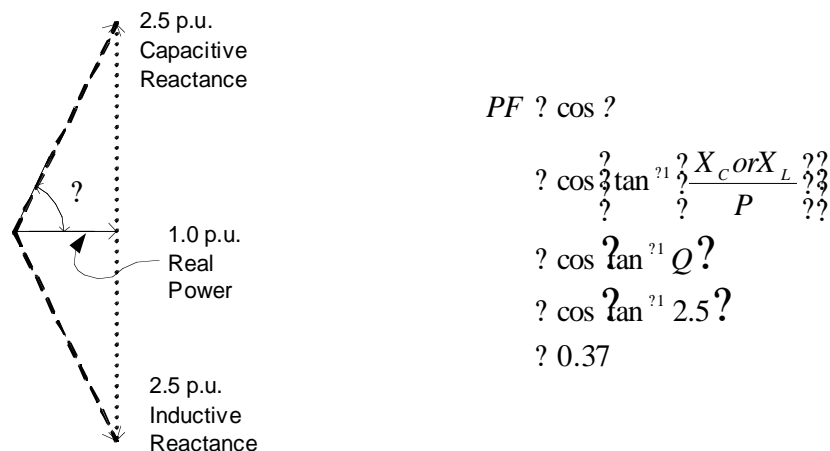


Figure 3 Relationship between Islanding Test circuit Q and power factor

This Q is intended to give a substantial safety margin over expected field values, and lower values are being considered for future certification requirements, subject to further review of field data³.

- c. **The islanded load circuit must be resonant within the under/over frequency trip settings.** This requirement implies that the capacitive reactance must be nearly equal to the inductive reactance of the islanded load. For a parallel RLC circuit

$$\omega_0 = \frac{1}{\sqrt{LC}} = 2\pi f_0; \quad C = \frac{1}{\omega |X_C|}; \quad L = \frac{|X_L|}{\omega}; \quad \text{therefore} \quad \left| \frac{X_C}{X_L} \right| = \left(\frac{f_0}{f} \right)^2$$

where

f_0 = resonant frequency of the RLC circuit, which must be within the trip settings (Rule 21 nominal values are 59.3 and 60.5 Hz)

f = fundamental frequency = 60 Hz

For the trip settings defined in Rule 21—60.5Hz and 59.3Hz or -1.2%/+0.8%—this relationship requires that the X_C must be within the range of -2.3%/+1.7% of X_L .

- d. **The load and GF output within the island must be stable.** The previously listed conditions must remain within the stated boundaries for the island to persist. Such stability increases in likelihood with increasing GF penetration due to increasing load diversity. At low penetration, turning on or off a single load can lead to an imbalance in Load/Generation or X_L/X_C .
6. **Legacy Synchronous Generators.** A particular concern exists with legacy synchronous generators installed under earlier Rule 21 requirements having only under/over voltage and frequency relays. These units are subject to the same Load/Generation ratio requirements stated above but may be able to extend the range if they attempt to regulate voltage. Depending on the relative capacity and penetration of other Rule 21-compliant GF within the island, these legacy synchronous machines can provide a very stable source and greatly increase the likelihood of unintentional islanding.

7.1.1 Potential Solutions

The non-export options defined in Screen 2 offer suitable anti-islanding protection. Exporting GFs that are certified non-islanding, as defined in Section J.3 of Rule 21, also provide suitable anti-islanding protection.

Other methods that might address the islanding concern include

³ For Example, the UK Standard G77 *UK Technical Guidelines For Inverter Connected Single Phase Photovoltaic (PV) Generators Up To 5 kVA*, requires a test load Q of 0.5.

- Transfer trip
- Non-certified Non-Islanding equipment
- Applicant may add protective functions to detect Distribution System faults
- EC or Applicant may add equipment to detect Distribution System ground faults
- Low GF Penetration (15% line section peak)
 - Low load diversity
 - Highly variable load
- Characteristics of generator output profile relative to load time-of- use profile (may indicate substantive compliance with minimum load criteria).
- EC may add voltage reclose blocking to Line Section automatic sectionalizing device.
- EC may revise recloser settings at Line Section automatic sectionalizing device
- EC may reconfigure Line Section

7.1.2 Unintentional Islanding Review Process

The flow chart in Figure 4 below and the description that follows provide a Supplemental Review Screen for situations in which Islanding is of concern. The result of this evaluation is either 1) no concern exists, so review the next issue or 2) additional review of the system is necessary. If further review (including a system impact study) is determined to be necessary, the successive sections provide guidance as to what additional data might be obtained, and what additional review should be performed. For reference, the questions are numbered and repeated here:

#	Question
Q1.	Applicant capacity What is the GF kW capacity of this Application?
Q2.	Applicant export What is the maximum expected export? Note that “0” means that one of the non-export options of Screen 2 has been met
Q3.	Applicant technology What is the technology (synchronous, induction, inverter) for this application?
Q4.	Certified Non-Islanding Does the proposed equipment include a Certified Non-Islanding function?
Q5.	Additional Features Does the proposed GF incorporate any additional features beyond those required in Rule 21 or unique operational characteristics that should be considered?
Q6.	Aggregate percentage What is the aggregate generating capacity relative to the peak Line Section load (in %)?
Q7.	Aggregate export What is the aggregate peak export on the Line Section relative to the peak Line Section load?
Q8.	Aggregate technologies What are the technologies of other GF on the Line Section?
Q9.	Relative capacities What are the relative capacities of other GF on the Line Section?
Q10.	Location Where is the Applicant GF relative to other GF on the Line Section?
Q11.	Unique features Are there unique operating/design features for the affected Line Section?

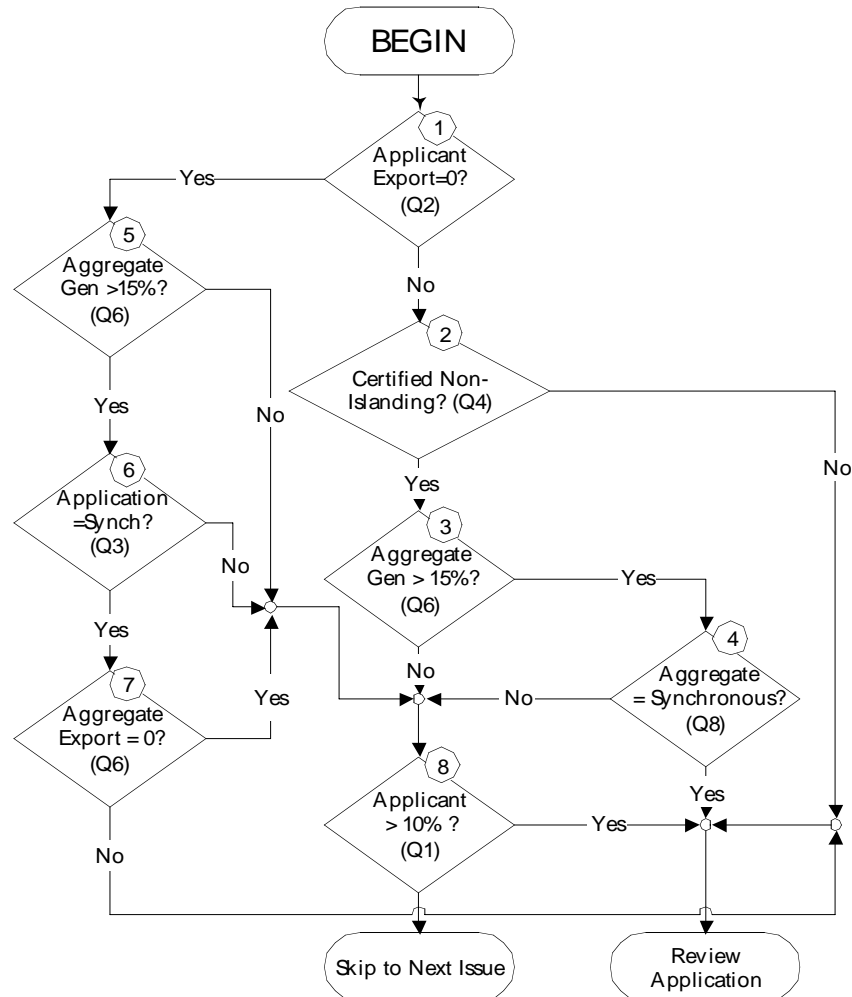


Figure 4. Unintentional Islanding Review Process

IF

1. Applicant GF is Non-Exporting (Q2= 0 kW)

OR

2. GF is Certified Non-Islanding(Q4 is True)

AND

3. The Aggregate Generation does not exceed 15% of the Line Section peak load ($Q6 \leq 15\%$),

OR

4. Other installed GF on the circuit are not Synchronous machines (Q8 does not include synchronous)

AND

5. The Aggregate Generation does not exceed 15% of the line segment peak load ($Q6 \leq 15\%$),

OR

6. The Applicant GF Technology does not includes synchronous machines (Q3 does not include synchronous)

OR

7. All of the other GFs are Non-Export ($Q7 = 0$),

AND

8. The capacity of the Applicant GF does not exceed 10% Line Section peak load ($Q1 \leq 10\%$)

THEN

Application does not present a potential islanding concern, skip to the next issue.

OTHERWISE

Application presents a potential islanding concern; continue review using guidance in the following sections.

7.1.3 Additional Data Required from Applicant

Responses to Q5 Additional Features that are relevant to the issue of islanding include the following:

- A description of Exporting GF controls and protective functions that actively limit the magnitude of it export, if available.
- Data showing correlation of generator output and customer or line-section load. This may be particularly relevant with solar systems, since the solar resource is often limited or non-existent during minimum load periods.
- Test reports from reliable source showing successful anti-islanding capability of non-certified equipment.

7.1.4 Additional Review Required by EC

As part of supplemental review, the following steps may need to be performed for systems that are determined to present potential islanding concern.

- Relative Capacities (Q9)
- Location on Line Section (Q10)
- Unique Features of Line Section (Q11).

If no reasonable solution results from the above review, an Interconnection Study, as described in the next section may be warranted.

7.1.5 Potential Interconnection Study Items

Should the Supplemental Review fail to define an appropriate solution, the following issues may need to be addressed in a more detailed interconnection study.

- Other GF on Line Section/circuit (capacities, types (synchronous, induction, inverter), modes of operation)
- Recloser intervals at sectionalizing device (circuit breaker, service restorer)
- Fault detection requirements

- Transfer Trip requirements.

7.2. Voltage Regulation

The impact of GFs on EC voltage regulation can be classified by four export levels. The discussions below consider only the impact of current flow and assume the GF is not attempting to regulate EC voltage. While these discussions focus on potential detrimental effects, under low to moderate penetration, these facilities are as likely to have no impact or provide some voltage support as they are to be detrimental.

Note that the term “downstream” implies current flow in the normal radial direction, from the Substation towards customer loads.

1. Non-export
With respect to voltage regulation, non-exporting GF simply appear to be negative loads. Voltage compensation equipment operation should not be impacted by the presence of GF anymore than switching on or off an equivalent load. For non-export GF, no further analysis is needed with respect to voltage regulation.
2. Low Penetration Export
Power exported to the EC distribution system causes a reverse voltage profile from the PCC to the point where the aggregate downstream load exceeds the GF output, such as point “A” in Figure 5.

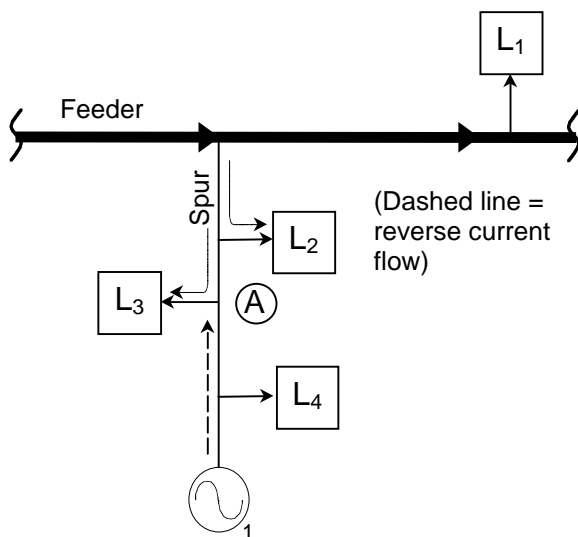


Figure 5 Exporting GFs cause reverse current flow up to point A where aggregate load ($L_3 + L_4$) exceeds aggregate GF output.

In terms of voltage regulation, this reverse flow is not a concern unless the magnitude of the current at some point approaches a percentage of the line section peak and where the corresponding voltage drop becomes significant. At low levels of penetration and high load conditions, Exporting GF, even under reverse current flow, should not be detrimental.

3. Moderate Penetration Export:

In Figure 6, the exporting GFs provide more current than is required by loads L_2 and L_3 and create reverse current flow in the spur. The remaining current reaches the main feeder at B and supports downstream feeder loads. The current flowing downstream at B reduces the current through the voltage regulation equipment (VR). The voltage drop in the feeder downstream of B will be the same as without GF. However, regulation equipment reacting to voltage and current flow at VR may operate at a lower boost setting, as if the downstream load was lower (by the amount produced by the GF). However, the problem (relative to no GF) will be offset by the fact that the voltage at B will be increased by the reduction of load on the spur plus the voltage rise due to current injection by the GF. This condition is most apparent when the GF is concentrated just downstream of VR, and the load is concentrated at the end of the feeder.

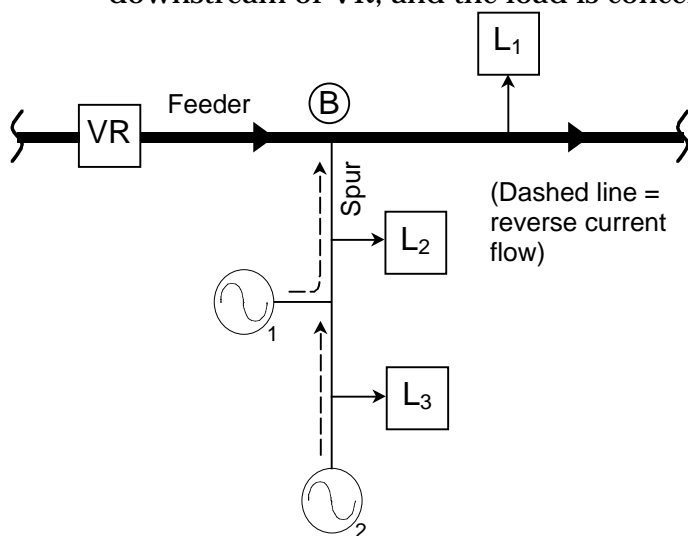


Figure 6 Exporting GFs cause reverse current flow up to point B where aggregate load exceeds aggregate GF output. Voltage Regulation equipment (VR) may not boost voltage sufficiently.

4. High Penetration Export:

Finally, Figure 7 shows a feeder section where the GF's aggregate export exceeds the load downstream from the EC regulation equipment VR. If VR is not sensitive to the direction of current flow, it may attempt to boost the voltage based on the absolute current flow. This condition is most problematic when the GF are concentrated at the end of the feeder and the loads are concentrated near VR.

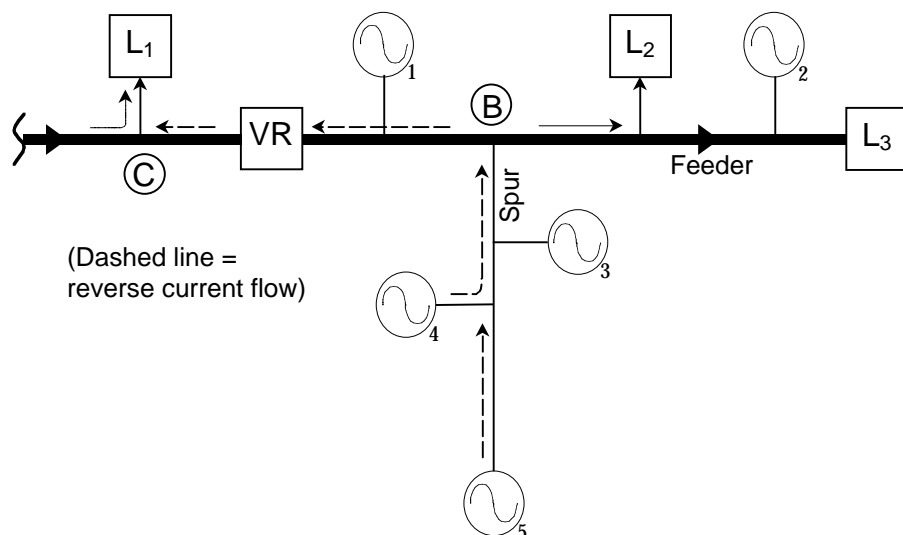


Figure 7 Exporting GFs cause reverse current flow on the spur and on the feeder up to point C where aggregate load exceeds aggregate GF output. Reverse current flow through Voltage Regulation equipment (VR) may cause misoperation.

7.2.1 Potential Solutions

With respect to voltage regulation, low penetration of GFs (exporting and non-exporting combined) as defined in Screen 4 (Aggregate DG capacity less than 15% Line Section Peak Load) should pose no significant concern.

Generating Facilities downstream of EC voltage regulation equipment with an aggregate exporting capacity less than 15% of regulator peak should pose no significant concern regarding regulator operation. Higher levels may be allowed without further review for GFs located near the end of the feeder. If feeder reverse current flow through uni-directional voltage regulation equipment is anticipated, equipment modification or replacement may be warranted.

Control schemes on some GFs may be set up to provide voltage support, sourcing or sinking VARs as directed, or to make the generation “voltage neutral” by sinking VAR’s to offset power export.

- EC replace/upgrade voltage regulating equipment
- EC replace/upgrade line capacitors or controls
- EC reconfigure Line Section

7.2.2 Voltage Regulation Review Process

The flow chart in Figure 4 below and the description that follows provide a Supplemental Review Screen for situations in which Islanding is of concern. The result of this review is either 1) no concern exists, so review the next issue or 2) additional review of the GF is necessary. If further review is determined to be necessary, the successive sections provide guidance as to what additional data might

be obtained, and what additional review should be performed. For reference, the questions are numbered and repeated here:

#	Question
Q1.	Applicant capacity What is the GF kW capacity of this Application?
Q2.	Applicant export What is the maximum expected export? Note that “0” means that one of the non-export options of Screen 2 has been met
Q3.	Aggregate export What is the aggregate peak export on the Line Section relative to the peak Line Section load?
Q4.	Relative capacities What are the relative capacities of other GF on the Line Section?
Q5.	Location Where is the Applicant GF relative to other GF on the Line Section?
Q6.	Unique features Are there unique operating/design features for the affected Line Section?
Q7.	Voltage regulation How is the distribution voltage regulated on the affected Line Section?

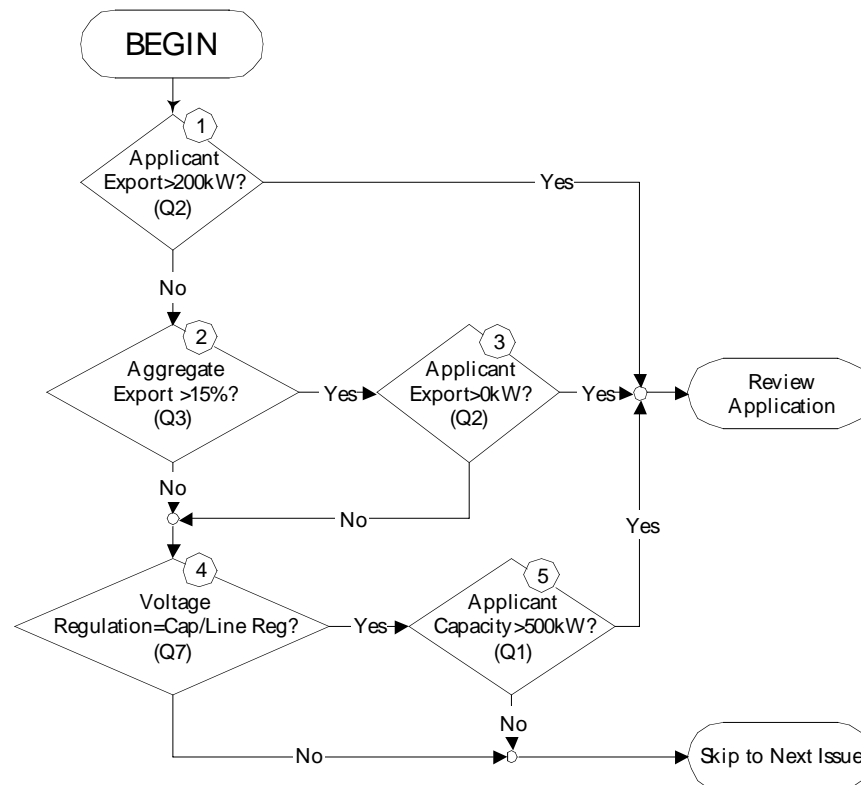


Figure 8. Voltage Regulation Review Process

IF

1. Applicant GF peak Export does not exceed 200kW ($Q2 \leq 200 \text{ kW}$)

AND

2. The Aggregate GF Peak Export does not exceed 15% of the Line Section peak load ($Q3 \leq 15\%$)

OR

3. The Applicant GF is non-exporting ($Q2 = 0$)

AND

4. Voltage Regulation on the line section ($Q7$) is not controlled by a Line Regulator or voltage-controlled switched Capacitor bank

OR

5. Applicant GF Capacity does not exceed 500 kW ($Q1 \leq 500 \text{ kW}$)

THEN

Application does not present a potential Voltage Regulation concern, skip to the next issue.

OTHERWISE

Application presents a potential Voltage Regulation concern; continue review using guidance in the following sections.

7.2.3 Additional Data Required from Applicant

A description of Exporting GF controls that actively limit the magnitude of export, if available, may be useful for addressing many of the issues listed in this section.

7.2.4 Additional Review Required by EC

- Relative Capacities ($Q4$)
- Location on Line Section ($Q5$)
- Unique Features of Line Section ($Q6$).

As part of supplemental, the following may need to be reviewed:

- Potential for feeder or voltage compensator/regulator backfeed.
- Voltage regulator control settings
- Other GF on Line Section or feeder (capacities, types (synchronous, induction, inverter), mode of operation)

7.2.5 Possible Decision Questions

Answers to the following questions may help determine if simple changes to the GF or EC equipment will facilitate acceptance of the application:

- What is the mix of the connected GF types? (If aggregate includes large synchronous unit(s), may trigger higher review level)
- Are there unique operating/design features of the connected EC Line Section that must be accounted for?

If either of the preceding questions lead to additional un resolved concerns, an EC Distribution System Impact Study may be warranted, as described in the next section.

7.2.6 Potential Interconnection Study Items

Should the Supplemental Review fail to define an appropriate solution, the following issues may need to be addressed in a more detailed EC Distribution System Impact Study.

- Load flow analysis to determine potential for feeder or voltage regulator/compensator backfeed.
- Distribution system load flow analysis- normal (peak and minimum load) and abnormal circuit configurations
- Voltage regulator control settings
- Other GF on Line Section or feeder (capacities, types (synchronous, induction, inverter), mode of operation)

7.3. EC Equipment Rating

At very high penetration levels, the aggregate export capacity of exporting GF may exceed EC's Distribution System normal or emergency equipment rating. Equipment of concern includes circuit breakers, fuses, service restorers, sectionalizers, voltage regulators, overhead conductors, underground cable, transformers etc.

7.3.1 Potential Solutions

If the Supplemental Review suggests that the rating of some EC equipment may be exceeded by the interconnection of an exporting GF, then either the GF controls will need to be modified or supplemented to limit its export, or EC equipment or controls will need to be modified, upgraded, or replaced.

7.3.2 EC Equipment Rating Review Process

The following process provides guidance as to when a particular application may pose a concern to EC equipment rating. This concern exists when the export capacity of the proposed GF or the aggregate export of all GF's on the line section exceed some minimum thresholds. For reference, the questions are numbered and repeated here:

#	Question
Q1.	Applicant export What is the maximum expected export? Note that “0” means that one of the non-export options of Screen 2 has been met
Q2.	Aggregate export What is the aggregate peak export on the Line Section relative to the peak Line Section load?
Q3.	Relative capacities What are the relative capacities of other GF on the Line Section?
Q4.	Location Where is the Applicant GF relative to other GF on the Line Section?
Q5.	Unique features Are there unique operating/design features for the affected Line Section?

IF

Applicant Export (Q1) \leq 200kW,

OR

Aggregate Export (Q2) \leq 10%?

THEN

Application does not present a potential EC equipment rating concern, skip to the next issue.

OTHERWISE

Application presents a potential EC equipment rating concern; continue review using guidance in the following sections.

7.3.3 Additional Data Required from Applicant

A description of Exporting GF controls that actively limit the magnitude of its export may be useful for addressing many of the issues listed in this section.

7.3.4 Additional Review Required by EC

As part of Supplemental Review, the following issues may need to be reviewed.

- Relative Capacities (Q3)
- Location on Line Section (Q4)
- Unique Features of Line Section (Q5).
- Equipment loading
- Other connected GF on Line Section/feeder (capacities, types (synchronous, induction, inverter), mode of operation)

7.3.5 Possible Decision Questions

The items below serve as a guide to determine if the application should be approved as is; approved with modifications to the Applicant's system, EC equipment, or both; or if an interconnection study is necessary.

If all of the following conditions are met, no additional requirements should be necessary

- Is 15% line section screen met (Screen 4)?

Answers to the following questions may help determine if simple changes to the GF or EC equipment will facilitate acceptance of the application:

- What is the mix of the GF types? (If aggregate includes large synchronous unit(s), may trigger higher review level)
- Are there unique operating/design features of the connected EC Line Section that must be accounted for?

7.3.6 Potential Interconnection Study Items

Should the Supplemental Review fail to define an appropriate solution, the following issues may need to be addressed in a more detailed EC Distribution System Impact Study.

- Distribution system load flow analysis- normal (peak and minimum load) and abnormal circuit configurations
- Equipment loading studies
- Other GF on Line Section/feeder (capacities, types (synchronous, induction, inverter), mode of operation)

7.4. EC Equipment Short Circuit Current Rating

The equipment ratings may need to be verified to ensure that the additional short circuit duty contributed by the GF will not exceed the ratings of existing equipment.

- EC's Distribution System equipment serving the GF and neighboring customer loads should be checked to verify that the short circuit ratings are not exceeded by the addition of the proposed GF. (Concerns include equipment ratings, both momentary and interrupting - circuit breakers, service restorers, sectionalizers, fuses, service equipment, etc.)
- Neighboring customer equipment connected to the EC's primary Distribution System or connected to a shared secondary to which the generation is added should be checked to verify that the short circuit ratings are not exceeded. (Concerns include equipment ratings, both momentary and interrupting - circuit breakers, service restorers, sectionalizers, fuses, service equipment, etc.)

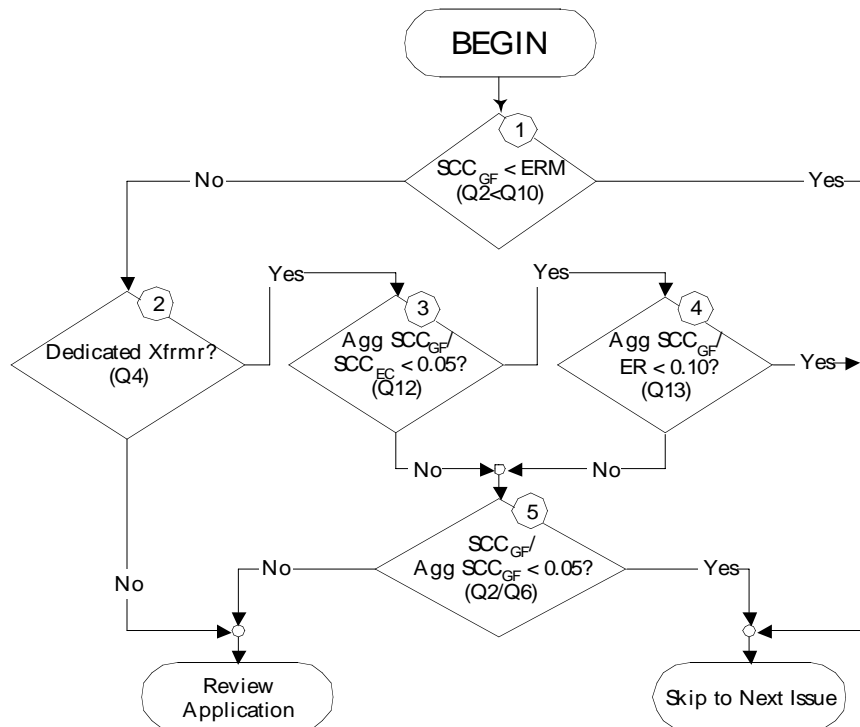
7.4.1 Potential Solutions

- EC replace/upgrade Distribution System elements
- EC/Applicant Install current limiting devices (fuses, reactors, ?).
- EC reconfigure the circuit to redistribute the generation with respect to the affected equipment
- Replace/upgrade underrated neighboring customer equipment

7.4.2 EC Equipment Short Circuit Current Rating Review Process

For reference, the questions relevant to this evaluation are numbered and repeated here.

#	Question
Q1	Applicant SCCR (from IRP) – What is the GF SCCR of this Application?
Q2	Applicant Short Circuit Current SCC_{GF} - What is the short circuit current contribution in amperes (or MVA) of the Applicant's GFs?
Q3	Maximum Continuous Short Circuit Current Capability – What is the Applicant GF sustainable fault current (after 2 seconds) output capability into a 3-phase high-side fault?
Q4	Dedicated Transformer – Is the GF served by a dedicated transformer?
Q5	Aggregate GF Short Circuit Current ($Agg\ SCC_{GF}$) – What is the total short circuit current contribution in amperes (or MVA) from all of the GFs if they were connected at the same location? $Agg\ SCC_{GF} = SCC_{GF1} + SCC_{GF2} + SCC_{GF3}$
Q6	Aggregate SCCR (from IRP) – What is the aggregate generator SCCR on the Distribution Circuit?
Q7	Protective Device Sensitivity - For EC Protective Devices: Expressed as a multiple of minimum trip, MMT (ratio of the end of line fault duty to the relay minimum trip), for overcurrent devices or expressed as a percent of reach, %Z , for impedance devices. These values are calculated without the proposed GF.
Q8	Relay Desensitization - What is the effective desensitization of the EC relays due to DG short circuit current in-feed?
Q9	Equipment Rating (ER) – What are the short circuit current ratings, in amps or MVA, of the equipment on the Distribution Circuit?
Q10	Equipment Rating Margins (ERM) – What are the margins, in amps or MVA between the equipment short circuit ratings on the Distribution Circuit and the maximum calculated short circuit duties. This information will be available from a previous fault study.
Q11	EC Substation SCC (SCC_{EC}) – what is the short circuit current contribution at the source substation or the maximum fault duty on the distribution circuit
Q12	$AggSCC_{GF}/SCC_{EC}$ Ratio – What is the ratio of the aggregate GF Short circuit current from (Q5) to the EC Substation SCC (Q11)?
Q13	$AggSCC_{GF}/ER$ Ratio – What is the maximum value of the ratios of aggregate GF Short circuit current from (Q5) to the Equipment Ratings (Q9)?



IF

1. The APPLICANT SCC_{GF} is less than the existing EQUIPMENT RATING MARGINS

OR

2. Dedicated Transformer is True

AND

3. The AGGREGATE SCC_{GF} is less than 5 % of the EC Substation SCC

AND

4. The AGGREGATE SCC_{GF} is less than 10 % of the EQUIPMENT RATINGS

OR

5. The APPLICANT SCC_{GF} is less than 5 % of the AGGREGATE SCC_{GF}

THEN

Application does not present a potential concern with respect to equipment short circuit rating, skip to the next issue.

OTHERWISE

A Fault Study is necessary to determine if any equipment ratings are exceeded.

7.5. Protective Device Sensitivity and Coordination

- It is a common EC practice to maintain the level of protective relay performance that existed on a circuit prior to the circuit modifications.
- The EC and neighboring customer protective devices may be de-sensitized by SCC from the proposed GF. In this case, the fault may not be cleared or may be cleared too slowly to protect the circuit adequately.
- The EC protective devices must be capable of detecting and clearing all bolted faults even with the addition of generation.
- For GF requiring fault detection, the GF protective devices must be capable of detecting and clearing all bolted faults within its protective zone without relying on the sequential detection of the EC's protective devices.
- Overtripping of existing GF and EC protective equipment on adjacent circuits may occur when the EC or neighboring customers protective devices are de-sensitized due to the SCC from the proposed GF.
- When GFs are slow to trip or fail to trip due to protective device de-sensitization the EC Distribution System circuit could be reclosed out of synchronization with the GFs.
- There is more potential for unintended islanding when existing GF protective devices are de-sensitized due to SCC of the proposed GF.

Figure 9 shows the relationship between the currents and impedances used in the equations that follow

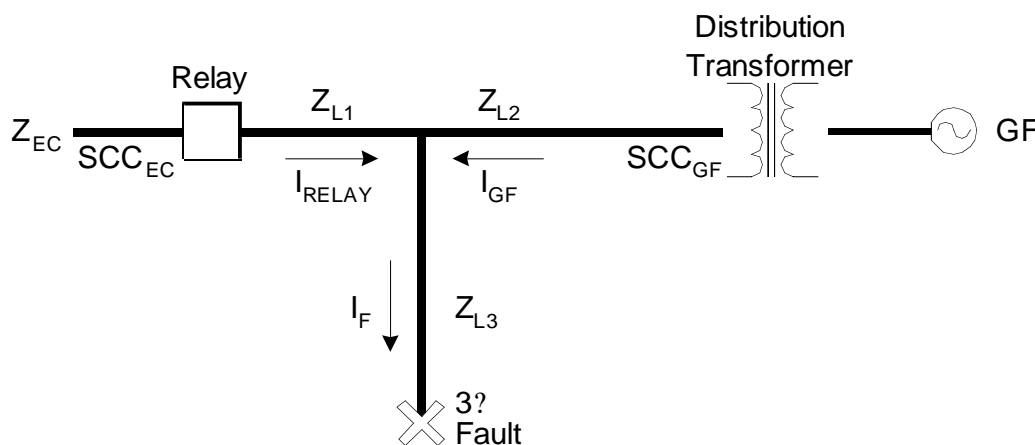


Figure 9 Relay desensitization example.

where:

Z_{EC} = EC source impedance at the relay location
 Z_{L1} = Impedance of line section L1

Z_{L2} = Impedance of line section L2

Z_{L3} = Impedance of line section L3

I_{RELAY} = Fault current flowing through relay

I_{GF} = Fault current provided by GF

I_F = Total fault current = $I_{RELAY} + I_{GF}$

I_{RELAY} is the fault current seen by the protective device for a fault at the end of line L₃.

When $SCC_{GF} = 0$; $I_{RELAY} = I_F$.

I_{RELAY_ACTUAL} is the fault current seen by the protective device for a fault at the end of line L₃ including the desensitizing effect of SCC_{GF}

$$\begin{aligned} I_{RELAY_ACTUAL} &= I_F \frac{Z_{L2} + \frac{1}{SCC_{GF}}}{Z_{EC} + Z_{L1} + Z_{L2} + \frac{1}{SCC_{GF}}} = I_F \frac{Z_{L2} * SCC_{GF} + 1}{\frac{1}{SCC_{EC}} + \frac{1}{SCC_{GF}}} \frac{1}{SCC_{GF}} \\ &= I_F \frac{Z_{L2} * SCC_{GF} + 1}{SCCR + 1} \geq I_F \frac{1}{SCCR + 1} \end{aligned}$$

This implies that for the maximum desensitizing effect due to SCC_{GF}

$$I_{RELAY_ACTUAL} \approx \frac{I_{RELAY}}{SCCR + 1}$$

Z_{RELAY} is the impedance seen by the protective device for a fault at the end of line L₃.

When $SCC_{GF} = 0$; $Z_{RELAY} = Z_{L1} + Z_{L3} = Z_F$

Z_{RELAY_APP} is the impedance seen by the protective device for a fault at the end of line L₃ including the desensitizing effect of SCC_{GF} .

$$\begin{aligned} Z_{RELAY_APP} &= \frac{V_{RELAY}}{I_{RELAY}} = \frac{Z_{L1} * I_F \frac{Z_{L2} * SCC_{GF} + 1}{SCCR + 1} + Z_{L3} * I_F}{I_F \frac{Z_{L2} * SCC_{GF} + 1}{SCCR + 1}} \\ &= Z_{L1} + Z_{L3} * \frac{SCCR + 1}{Z_{L2} * SCC_{GF} + 1} \leq Z_L * (SCCR + 1) \text{ when } Z_{L1} = Z_{L2} = 0 \end{aligned}$$

This implies that for the maximum desensitizing effect due to SCC_{GF} :

$$Z_{RELAY_APP} \approx Z_{RELAY} * (SCCR + 1)$$

Note: All values are in per unit.

7.5.1 Potential Solutions

- EC/Applicant Install current limiting devices (fuses, reactors, ?).
- EC reconfigure the circuit to redistribute the GF with respect to the affected equipment
- EC install dedicated transformer
- EC replace existing or install additional protective equipment to maintain adequate protection coordination and sensitivity (relays, fuses, grounding transformers, automatic reclosers, etc.)
- EC install transfer trip to mitigate out-of-synch reclosing, or fault detection problems,.
- GF may require additional protective equipment functionality to detect faults on EC Distribution System.
- GF may have to incorporate additional controls and monitoring

7.5.2 Protective Device Desensitization Review Process

For reference, the questions relevant to this evaluation are numbered and repeated here.

#	Question
Q1.	Applicant SCCR (from IRP) – What is the GF SCCR of this Application?
Q2.	Maximum Continuous Short Circuit Current Capability – What is the Applicant GF sustainable fault current (after 2 seconds) output capability into a 3-phase high-side fault?
Q3.	Aggregate SCCR (from IRP) – What is the aggregate generator SCCR on the Distribution Circuit?
Q4.	Protective Device Sensitivity - For EC Protective Devices: Expressed as a multiple of minimum trip, MMT (ratio of the end of line fault duty to the relay minimum trip), for overcurrent devices or expressed as a percent of reach, %Z , for impedance devices. MMT and %Z are calculated excluding the proposed GF; Protective Device Sensitivity+ (MMT+ and %Z+) include the proposed GF.
Q5.	Protective Device Margin Requirement – What is the EC-specified margin requirement (MMT or %Z)? This constant is typically 1.5 – 3.0 for MMT or 1.1 – 2 for %Z. .

Protective Device Sensitivity

$$MMT = \frac{I_{RELAY}}{I_{Relay_Minimum_Trip}}$$

$$\%Z = \frac{Z_{Relay_Minimum_Trip}}{Z_{RELAY}}$$

Protective Device Sensitivity+ with all generators connected to the circuit.

$$\text{MMT}^+ = \frac{I_{\text{RELAY_ACTUAL}}}{I_{\text{Relay_Minimum_Trip}}} = \text{MMT} / (\text{SCCR} + 1)$$

$$\%Z^+ = \frac{Z_{\text{Relay_Minimum_Trip}}}{Z_{\text{RELAY_APP}}} = \%Z / (\text{SCCR} + 1)$$

IF

1. AGGREGATE SCCR(Q3) < 0.5

AND

2. Protective Device Sensitivity⁺ (Q4) > Protective Device MARGIN REQUIREMENT (Q5)

THEN

Application does not present a potential Protective Device Desensitization concern, skip to the next issue.

OTHERWISE

Application presents a potential Protective Device Desensitization concern; continue review using guidance in the following sections.

7.5.3 Additional Data Required from Applicant

7.5.4 Potential Interconnection Study Items

Should the Supplemental Review fail to define an appropriate solution, the following issues may need to be addressed in Fault Study and Relay Coordination Review

- Maximum Continuous Short Circuit Current Capability (Q2)
- Check the coordination of the existing protective equipment and make adjustments and recoordinate as necessary.

7.6. Interaction of Generating Facility Controls

There are no documented control interaction issues at this time.

IF

There is a documented Interaction of Controls issue? (Issues would be documented on the CEC website.)

THEN

review application with respect to

- Applicant Technology,
- Aggregate Technologies
- Line Section Voltage Regulation.

If issues are discovered, the following solutions may be considered:

- Applicant provide additional control/monitoring
- EC reconfigure Line Section to avoid interaction issues

7.7. Open-Delta Regulation

Some 3-wire distribution circuits (especially in the rural areas) may have one or more stages of "open-delta" regulation (or open delta auto boosters, fixed boosters, etc.). These open-delta regulating transformers cause a standing zero sequence voltage when their taps move from the neutral position in either direction. This zero sequence voltage interferes with and can impair the voltage sensing ground fault detection schemes that are prevalent for 3-wire systems. Open-delta regulation is not an issue if ground fault detection is not used.

7.7.1 Potential Solutions

Closure of the "delta" by adding the 3rd regulating transformer, or replacement of the "open delta" with a "WYE" connected stage are among the common solutions. When a GF is to be interconnected downstream of these "open-delta" regulating transformers, possible problems arising from this configuration must be addressed and studied.

7.7.2 Open Delta Regulation Review Process

7.7.3 Additional Data Required from Applicant

7.7.4 Additional Review Required by EC

As part of supplemental review, the following steps may need to be performed.

-

7.7.5 Possible Decision Questions

-

7.7.6 Potential Interconnection Study Items

-

7.8. System Protection

This section describes guidelines for ensuring a generator installation using non-certified equipment will adequately meet the system protection concerns of the EC. The

protective functions and requirements of Rule 21 are designed to protect the EC's distribution system, not the GF.

System protection functions are the generator's prescribed requirements for disconnecting from the EC in the event of out-of tolerance conditions, including

- Under/over voltage
- Under/over frequency
- Synchronization
- Anti-islanding, if applicable
- Reverse or under power protection, if applicable

The requirements for these protective functions are summarized in Section 5. Also, where applicable

- Island detection and shutdown: within 2 seconds
- Reverse Power: Default setting shall be 0.1% (export) of transformer rating, with a maximum 2.0 second time delay.
- Under Power: Default setting shall be 5% (import) of GF Gross Nameplate Rating, with maximum 2.0 second time delay.

7.8.1 Potential Solutions

System protection is a major concern of the EC with respect to generator interconnections, and therefore the functions in non-certified equipment should either be:

- Supplemented with EC-approved protective relays or
- Tested and verified by the EC, NRTL, professional engineer, or other EC-approved testing entity.

7.8.2 System Protection Review Process

The description that follows provides a Supplemental Review Screen for situations in which equipment system protection functions are of concern. For reference, the questions relevant to this evaluation are numbered and repeated here.

#	Question
Q1.	Applicant export What is the maximum expected export? Note that "0" means that one of the non-export options of Screen 2 has been met
Q2.	Applicant technology What is the technology (synchronous, induction, inverter) for this application?
Q3.	Applicant technology experience Is the interconnection equipment the same or of a similar class as currently installed and approved in EC territory?
Q4.	External mitigation equipment Does the applicant design incorporate EC approved protective relays, filters, etc..., either as part of the Generator Facility or pre-existing in the customer facility?

- Review test results and reports provided by applicant for generator compliance with each of the protective functions defined.
- Review any documentation from applicant that attempts to provide reason or justification for not including test results or reports for specific protective functions.
- Evaluate the justifications using guidance from Section 7.8.4 below to determine if the data and reports provided are adequate for approval under the supplemental review.

7.8.3 Additional Data

- Documentation that is required for certified equipment must be provided, or substantiation as to why that documentation is not provided or needed (e.g. Test reports from other installations).
- Any GF-specific operational characteristics or features.
- If harmonic distortion greater than IEEE 519 requirement for generators, provide additional site load and harmonic data to verify compliance with Rule 21, Section D.2.d.

7.8.4 Possible Decision Points

The items below serve as a guide to determine if the application should be approved with modifications to the Applicant's system, EC equipment, or both; or if an interconnection study is necessary.

Basic Protective Functions

- If Applicant Technology Experience = True (Q3), and applicant satisfies EC requirements for prevention of unintended islanding, tests of voltage and frequency protective functions may be waived or reduced.
- If Existing facility equipment = True (Q4), tests of voltage and frequency protective functions may be waived or reduced as appropriate.
- If Q3 OR Q4 = True, EC may waive or reduce in scope as appropriate, additional basic protection tests such as dielectric voltage withstand, short-circuit, loss of control, surge withstand, in-rush current.

Potential for Unintended Islanding

- If Q1 = 0, no certification tests are required for anti-islanding
- If Q4 = True, and the existing protection includes reverse power, under power, or transfer trip at the EC point of interconnection, no certification tests are required for anti-islanding.

As standard procedure prior to system acceptance, the EC shall verify system shutdown and reset delay following loss of utility as part of standard pre-parallel inspection.

An interconnection study, as described in the next section may be warranted, if any of the conditions in the review process are substantially exceeded.

7.8.5 Potential Interconnection Study Items

Should the Supplemental Review fail to define an appropriate solution, the following issues may need to be addressed in a more detailed interconnection study.

- Protection equipment beyond supplemental review.
- Equipment necessary to mitigate power quality issues.
- Testing to characterize equipment.

7.9. Power Quality

This section describes guidelines for ensuring a generator installation using non-certified equipment will adequately meet the power quality concerns of the EC.

Generator power quality requirements include:

- Harmonics
- Power Factor
- DC injection, if applicable

The requirements for these functions are summarized in Section 5:

7.9.1 Potential Solutions

Power Quality concerns are important but in most case secondary to the system protection functions described in Section 7.8. While the generating unit is still subject to meeting the power quality requirements defined by Rule 21, documentation or testing documents addressing these requirements may, at the discretion of the EC, be less rigorous than those of the protective functions.

- Test documents, waveform reports, harmonic measurements, and other power quality documentation from equipment factory tests, product literature, or other informal sources may be adequate for the EC's purposes.
- Should the test documentation be considered inadequate by the EC for specific power quality functions, the EC may require additional testing by the EC, NRTL, professional engineer, or other EC-approved testing entity.
- If the generating equipment does not satisfactorily meet the power quality functional requirements, additional mitigation equipment such as filters or isolation transformers may be required.

7.9.2 Power Quality Review Process

The description that follows provides a Supplemental Review Screen for situations in which equipment power quality is of concern. For reference, the questions relevant to this evaluation are numbered and repeated here.

#	Question
Q1.	Applicant export What is the maximum expected export? Note that “0” means that one of the non-export options of Screen 2 has been met
Q2.	Applicant technology What is the technology (synchronous, induction, inverter) for this application?
Q3.	Applicant technology experience Is the interconnection equipment the same or of a similar class as currently installed and approved in EC territory?
Q4.	External mitigation equipment Does the applicant design incorporate EC approved protective relays, filters, etc..., either as part of the Generator Facility or pre-existing in the customer facility?

- Review test results and reports provided by applicant for generator compliance with each of the power quality functions defined.
- Review any documentation from applicant that attempts to provide reason or justification for not including test results or reports for specific power quality functions.
- Evaluate the justifications using guidance from Section 7.9.4 below to determine if the data and reports provided are adequate for approval under the supplemental review.

7.9.3 Additional Data

- . Documentation that is required for certified equipment must be provided, or substantiation as to why that documentation is not provided or needed (e.g. Test reports from other installations).
- Any GF-specific operational characteristics or features.
- If harmonic distortion for proposed generator exceeds the Rule 21 requirement, provide additional site load and harmonic data to verify Provider facility compliance with Rule 21, Section D.2.d.

7.9.4 Possible Decision Points

The items below serve as a guide to determine if the application should be approved with modifications to the Applicant’s system, EC equipment, or both; or if an interconnection study is necessary.

- Does applicant already include mitigation equipment at facility that will address power quality concerns?
- Does the applicant facility size have an impact on the power quality concern, e.g. in addressing IEEE 519 requirements described in Rule 21.
- Does the applicant have a dedicated transformer that may mitigate DC injection or harmonic concerns?
- If Export Capacity = 0 (Q1), tests for harmonic distortion may be waived or reduced in scope.
- If Export Capacity = 0 (Q1), tests for power factor control may be waived or reduced in scope.

- If Applicant Technology = Inverter (Q2) and Export Capacity = 0 (Q1), OR if applicant has a dedicated isolation transformer, EC may waive need for DC injection test reports.

An interconnection study, as described in the next section may be warranted, if any of the conditions in the review process are substantially exceeded.

7.9.5 Potential Interconnection Study Items

Should the Supplemental Review fail to define an appropriate solution, the following issues may need to be addressed in a more detailed Study.

- Protection equipment beyond Supplemental Review.
- Equipment necessary to mitigate power quality issues.
- Testing to characterize equipment.

Annexes

<This version contains no Annexes>